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AN INVESTIGATION OF THE FIVE POINT RESTRAINT SYSTEM FOR AVIATORS

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This report investigated a purported restriction on aircrew leg movements due to the anchor point location of the five point restraint system in the Advanced Attack Helicopter (AAH). The system was investigated with aviators wearing both body armor and survival vest. An adjustable AAH crew seat mock-up was used which contained production cushions with anti-torque pedals with toe brakes.

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Results showed that the current configuration would not restrict the leg motion of the pilot. However, the restraint system did interfere with the body armor and survival vest. This effect confounded the results.

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CONTENTS

AN INVESTIGATION OF THE FIVE POINT RESTRAINT

SYSTEM FOR AVIATORS

INTRODUCTION

The Advanced Attack Helicopter (AAH) Technical Management Office requested the US Army Human Engineering Laboratory (HEL) assess the Five Point Restrain Harness lap belt anchoring location after receiving conflicting information on leg motion restriction.

AAH contractor test pilots reported that the lap belt crossed too far forward on the thighs and restricted leg movement during pedal operation.[1] In response, the Human Engineering Group of the AAH contractor investigated the problem, and suggested that the anchor location be moved aft and lower than the present position.

Before requesting that the seat be modified, the AAH office contacted several Army test pilots who have flown the AAH to verify the problem. However, the Army test pilots did not verify the problem, and subsequently the HEL was contacted to provide additional data.

The initial study performed by the AAH contractor evaluated the restrain harness while the pilots were seated in a wooden seat which was adjusted to the design cushion compression lines. To provide a more realistic evaluation, the HEL investigated the restraint harness by using a set of production cushions while the pilots wore body armor and a survival vest. Cushion probes were used to locate the seat reference point (SRP). The procedure is explained in the appendix.

OBJECTIVES

The objectives of this investigation were as follows:

1. To determine if the presently designed restraint harness, as attached in the AAH, provides sufficient leg movement and anti-submarining restraint.

2. To investigate the interaction of the restraint harness with body armor and the survival vest.

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[1]Hughes Helicopters. YAH-64 Advanced Attack Helicopter Report, Crew Station Geometry (Report No. 77-HF-0008-2). Prepared for Project Manager, Advanced Helicopter, St. Louis, MO, December 1979.

DESCRIPTIONS

The Five Point Restraint System is shown in Figure 1. The web widths for the shoulder, lap, and crotch straps are 2, 2-1/4, and 1-3/4 inches, respectively. The shoulder and lap straps are released by a quarter turn of the release hub.

Figures 2 and 3 show the body armor and survival vest used during the evaluation. The vest contains actual and mockup survival gear except for the weapon and holster which are normally mounted under the pilot's left arm.

To evaluate the lap belt anchoring points, a fully adjustable AAH crew seat and anti-torque pedal assembly was constructed which exposed the pilot's torso while providing correct cushion support (Figure 4). Alternate anchoring points were used which ranged from 2 inches forward to 3 inches aft of the present position. These were arranged in a line parallel to the seat bottom at 1-inch intervals.

Six-inch long cushion probes (Figure 5) were inserted through the seat cushions to check the SRP since the lap belt anchor point location is referenced from the SRP. The probe arrays were designed to colocate with specific body points and reconstruct the two planes which define the SRP. Additional information relating to the location of the SRP is contained in the appendix.

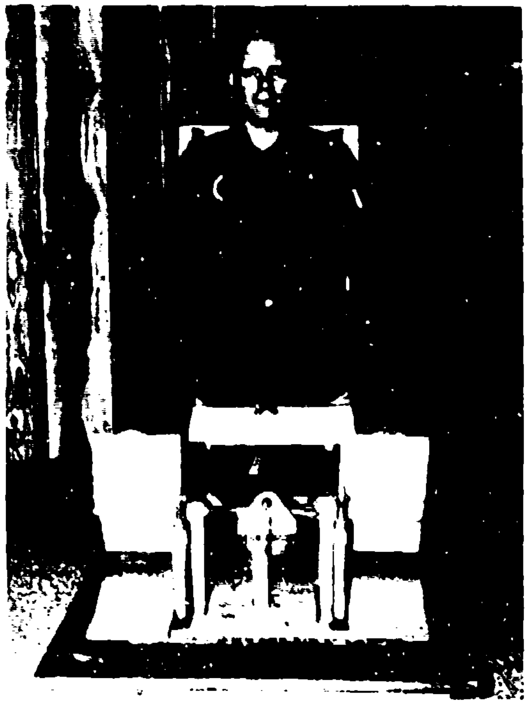
Figures 4 and 5 show the lumbar support can be adjusted in height with hook and file fasteners.

The forward and aft AAH crew stations contain the same fully armored seat except that the forward crew seat is canted three degrees rearward with respect to the horizontal. Both seat backs cant 10 degrees rearward with respect to their seat bottoms.

METHOD

Subjects

The subjects used during the evaluation were stationed at Aberdeen Proving Ground, MD, and no preliminary criteria were used to select them for participation in this evaluation. Table 1 lists the subjects and a series of anthropometric measurements.



a. Full body view of restraint system.

b. Close-up of restraint system anchoring point.

Figure 1. Five point restraint system.

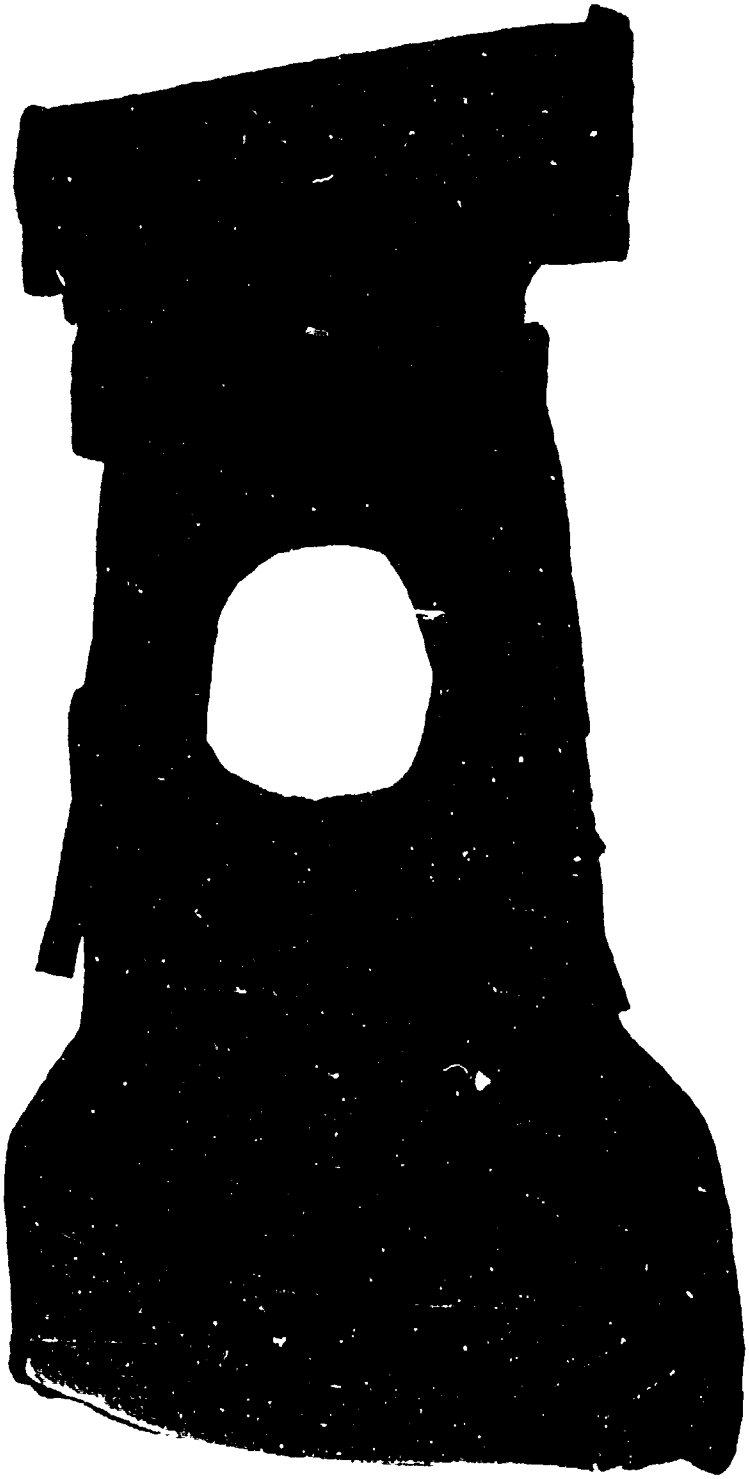


Figure 2. Body armor fragmentation small arms protective vest, aircrewman, M-73.

Figure 3. Aircrewman mesh net survival vest, SRO-21/P (USAF Drawing 66D1596).

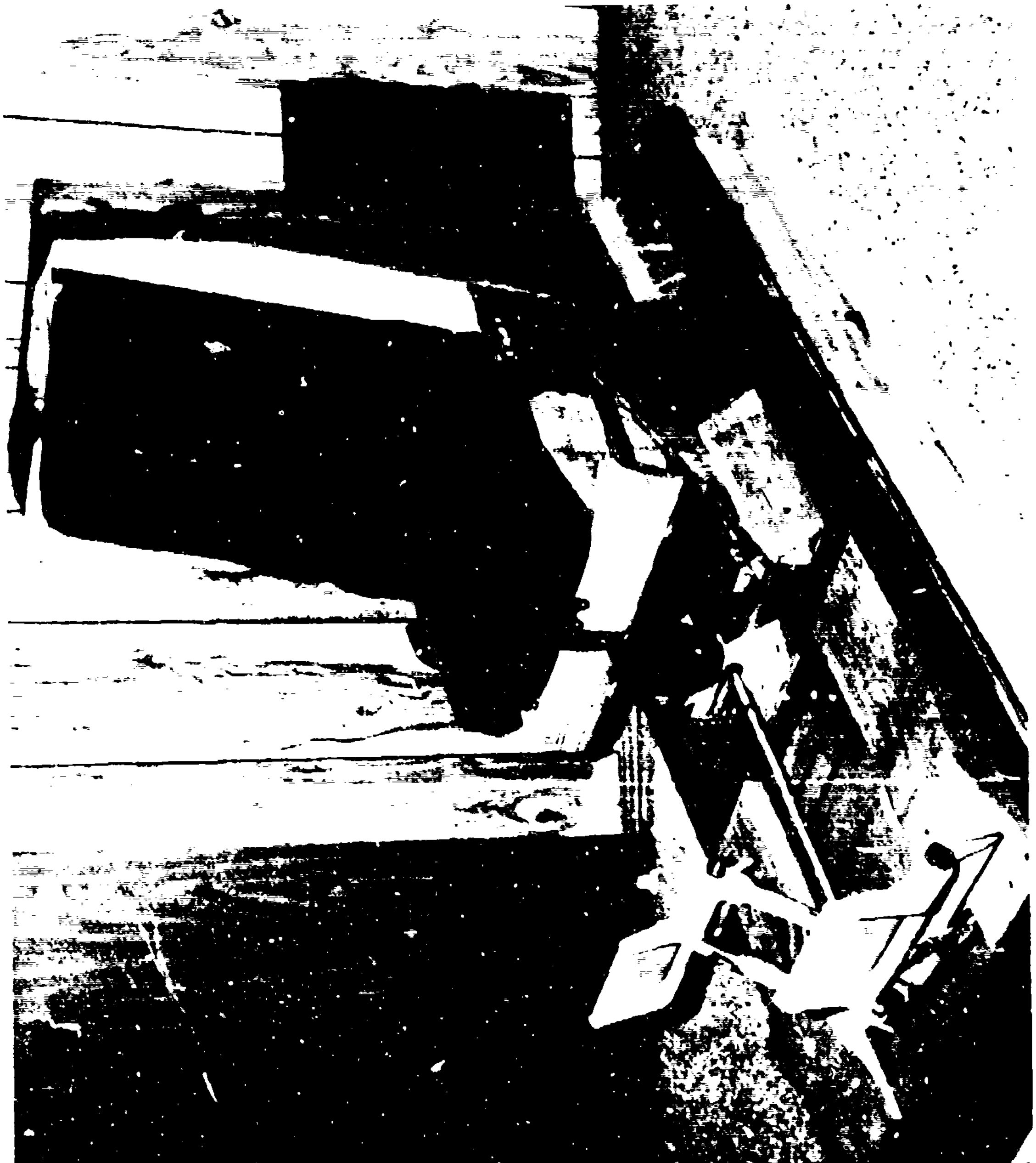


Figure 4. Seat assembly.

Figure 5. Cushion probes.

TABLE 1

Subject Data - Clothed
(Centimeters)

Subject	Height	Weight (Pounds)	Age	Thigh Clearance Sitting	Upper Thigh Circumference	Hip Breadth Sitting	Hip Circum-ference	Waist Circum-ference	Chest Circum-ference	Vertical Trunk Circumference Sitting
MF	183.8	200	53	14.2	59.0	38.2	102.5	94.0	104.8	174.0
DY	174.3	187	37	16.6	63.0	36.6	102.5	90.0	98.2	163.5
HB	181.3	195	31	18.2	64.7	38.2	107.5	89.5	98.5	166.5
TF	186.5	228	36	19.4	67.8	40.0	108.2	102.0	116.5	182.8
JW	172.8	155	43	12.6	54.0	34.0	93.0	81.0	98.3	154.0
DH	-	-	-	-	-	-	-	-	-	-
PG	177.5	182	32	17.2	63.5	35.2	103.0	92.8	98.0	163.0
CF	176.4	180	50	13.4	59.8	36.9	99.4	94.2	103.6	170.0

Procedure

The subjects were asked to sit in the crew seat and adjust the lumbar support to where it felt comfortable. The seat was then adjusted to place them as close as possible to the design eye position. They were then secured in the seat with the harness adjusted to the desired tension. An initial attempt to provide equal lap belt tension through the use of a thigh blood pressure cuff proved futile because the cuff could not be positioned correctly under the lap belt. The anti-torque pedals were then adjusted to the subject's desired position for flight and full brake actuation.

Figure 6 illustrates the measurements that were obtained. The angle of pull for the lap belt was found by aligning an Abney level with the anchor point, and the crotch belt angle was obtained by placing the Abney level on the belt itself. The lumbar height was measured to the anchor position on a line parallel to the seat back. The SRP was calculated by locating the longest protruding cushion probes within the probe arrays.

As the subjects operated the pedals, they were asked if the belt would either hinder their leg motion or provide undue pressure on their thighs.

A - Upper Torso Position
B - Lower Torso Position
C - Buttock Position
D - Lumbar Height
E - :ap Belt Angle
F - Anti-Torque Pedals
G - Anchor Point Height
H - Anchor Point Forward
I - Eye Height
J - Eye Position Forward
K - Crotch Strap Angle

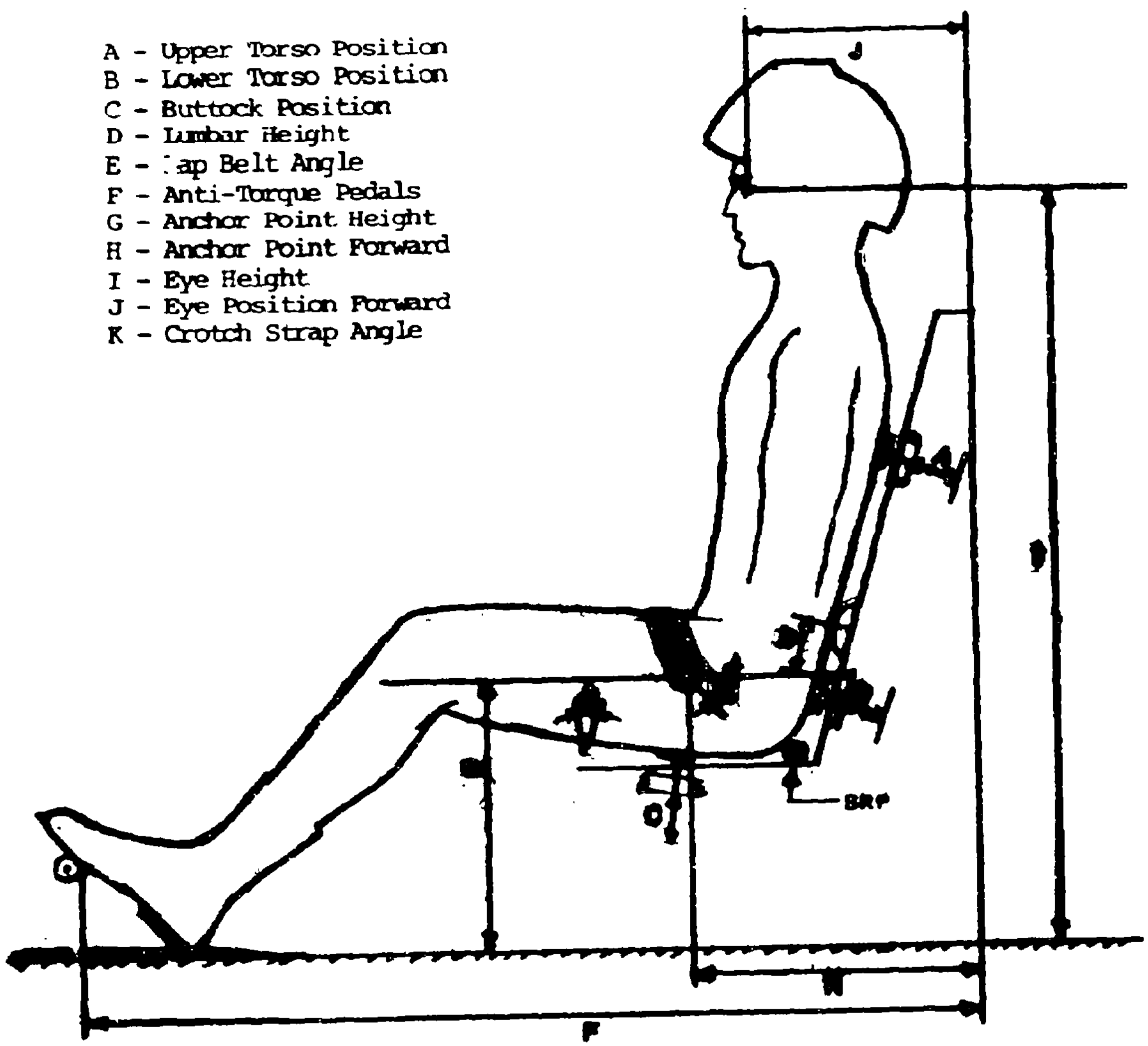


Figure 6. Measurement locations.

The lap belt anchor point was then varied and the subjects commented on the alternate position. Each subject did not evaluate all anchor positions. Lap belt positions forward of the present design position were used to find if additional restriction to leg movement could be detected. If no differences were detected, intermediate positions were not used. They were then fitted with the appropriate protective gear and resecured into the seat.

RESULTS AND DISCUSSION

The following results were obtained from this evaluation:

a. The lap belt did not bind the subjects' thighs.

b. The body armor and survival vest significantly interact with the fit of the restraint system.

c. The seat reference point was found to be 0.75 inch forward and 0.25 inch above the designed point.

The subjects' comments relative to the interaction of the seat belt with their legs are listed in Table 2.

Table 3 gives the lap belt tension angle measured at the anchor point.

There is a general decrease in the lap belt angle as the anchor location was moved farther aft from the design position. The angle was decreased an additional seven degrees when the subjects wore both the body armor and survival vest. The inflection in the data which occurs 1 inch aft of the present position was caused by the release mechanism beginning to reseat against the subject's torso and body armor. The gaps in the table occur because the subjects could not discern a difference and data was not obtained at those intermediate conditions.

Table 4 gives the crotch strap tension angle measured from the horizontal.

In general the crotch strap was not in tension when the subject wore the body armor and survival vest. The reversals in the data (subjects showed a lesser angle with body armor) occurs because the top of the attaching mechanism rests on the body armor and is canted forward. This results in the crotch strap attachment rotating rearward and decreasing the angle.

Figures 7 and 8 show subjects "TF" and "DH" with the lap belt anchored 2 inches aft of the present location. This position was suggested by the contractor as an alternate anchor position.

Figures 9 through 16 display the general fit of the restraint harness while wearing the body armor and survival vest.

TABLE 2

Subjects' Comments

Record	Condition*	Anchor Point	Subjects' Comments	General Comments
1JW	AV	+1°	Does not bind	Crotch strap is loose
2JW	AV	-2°	Feels that the belt is pulling him into the seat more - belt starting to bind on top	Cinch is farther aft on thighs - crotch strap not as loose
19JW	AV	FP		Crotch strap is loose
21JW	S	-2°	Does not bind	Crotch strap is tight
22JW	S	+1°	Does not bind	Crotch strap is tight
23JW	S	FP	Does not bind	Crotch strap is tight
24JW	S	-1°	Does not bind	Crotch strap is tight
3TF	FS	-2°	Impinges at the hub from latches on inner thighs	Crotch strap is tight
4TF	AV	-2°	Some binding but will not hinder flight	Crotch strap is loose - belt under breast plate - lap belt all the way out
5TF	AV	+1°	Tension felt on thighs, especially on cinch	Crotch strap tight - belt under breast plate
6DY	FS	+1°	Feels good, no problems	Crotch strap tight
7DY	AV	+1°	Feels good, no problems	Back is rounded in seat, probes not contacting back
8DY	AV	+1°	No restrictions	Crotch strap loose
9HB	FS	+1°	Pressure felt on outer thighs on pedals and on inner thighs when on brakes	Subject required more pedal adjustment than AAH provided - this resulted in an uncomfortable thigh tangent angle and more belt binding
10HB	FS	-1°	Pressure isn't as great on inner and outer thighs	Belt binding up in hub latches
11HB	AV	-2°	Belt starting to cut on top of thighs	
12HB	AV	-2°	Chafing on neck	Crotch strap loose - plate pushing - on buckle
13HB	AV	-1°	Binding on outer portion of upper thighs	
14HB	AV	+1°	More comfortable when cinch under plate than over plate	
13DH	FS	+1°	No problems	Crotch strap tight
14DH	AV	+1°	Pressure but no binding	Crotch strap very loose
15DH	AV	-2°	Doesn't feel any binding	Hub pad riding above radio on right side
15MF	S	FP	No restrictions	
16MF	AV	FP	No restrictions	Crotch strap loose - cinch under plate while plate resting on belt
17MF	AV	-2°	No difference in feel than present position	Crotch strap loose
18MF	AV	+1°	Binding a little worse	Crotch strap loose
22PG	FS	-2°	No binding	Crotch strap tight
23PG	FS	FP	No binding	Crotch strap tight
24PG	AV	FP	Binding on top of thigh but could last the flight	Crotch strap loose
25PG	AV	-2°	Not as much contact on thigh	Crotch strap loose
26CF	S	-2°	No binding	
27CF	S	+1°	Feels the pressure from the belt	
28CF	S	FP	No objections	
29CF	AV	FP	Some binding in crotch over thighs	Crotch strap tight
30CF	AV	-2°	Binding a little worse than present position	Belt riding up in hub latches

*AV = Armor plated + survival vest; FS = Flight suit; S = Street clothes.

TABLE 3

Lap Belt Tension Angle
(Degrees From Horizontal)

	Anchor Location Measured From Present Position							
	-2"		-1"		PP		+1"	
Body Armor	W[a]	WO[a]	W	WO	W	WO	W	WO
Subject								
JW	48.0	45.5	43.5	53.5	44.0	56.0	60.5	61.0
TF	55.0	59.5	-	-	-	-	74.5	-
DY	-	-	55.5	-	-	-	70.5	63.6
HB	54.0	57.5	58.5	66.0	-	-	68.0	73.5
DH	45.5	-	-	-	-	-	65.0	71.0
MF	99.5	-	-	-	55.0	55.0	61.0	-
PG	44.5	45.0	-	-	53.5	61.5	-	-
CF	41.0	73.0	48.5	-	-	53.5	-	61.5
$\bar{X}$	49.4	56.1	51.5	59.8	50.8	56.4	66.6	67.1
S	4.3	11.6	6.8	8.8	6.0	3.6	5.5	6.6
N	6	5	4	2	3	4	6	5
Δ	6.7		8.3		5.6		0.5	

[a]W = With body armor; WO = Without body armor.

TABLE 4

Crotch Strap Tension Angle

Anchor Location	-2"		-1"		PP		+1"	
Body Armor	W[a]	WO[a]	W	WO	W	WO	W	WO
Subject								
JW	57.0	54.0	L	53.5	L	56	58.5	57.0
TF	L[b]	7.5	-	-	-	-	79.0	-
DY	-	-	64.0	-	-	-	73.0	78.5
HB	L	68.0	67.5	72.5	-	-	71.0	70.5
DH	L	-	-	-	-	-	L	58.0
MF	L	-	-	-	L	67	L	-
PG	L	69.0	-	-	L	69	-	-
CF	67.5	53.5	78.0	-	-	73	-	75.0

[a]W = With body armor; WO = Without body armor.
[b]L = Too loose to measure.

Figure 7. Anchor point 2 inches aft of present position, subject TF.

Figure 8. Anchor point 2 inches aft of present position, subject JW.

Figure 9. Subject MF, side view, forward anchor location.

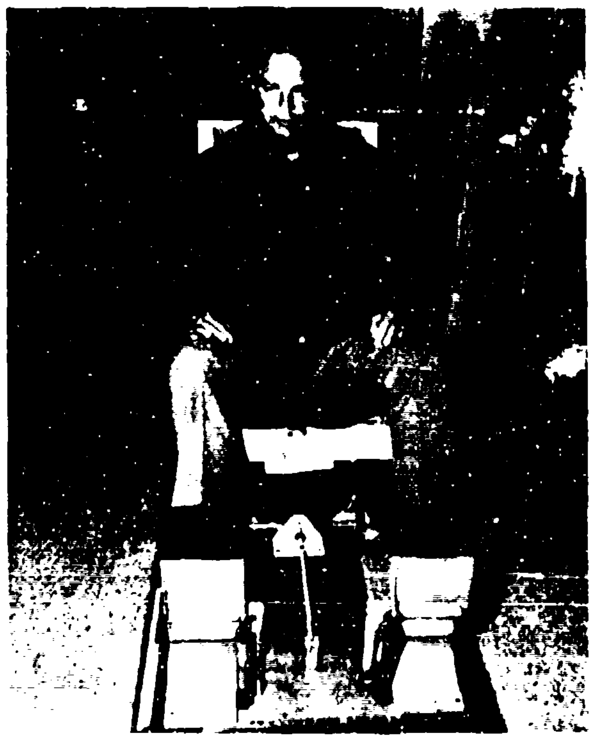


Figure 10. Subject MF, front view, forward anchor location.

Fig. 11. Subject MF, side view, aft anchor location.

Figure 12. Subject MF, front view, aft anchor location.

Figure 13. Subject CF, side view, aft anchor location.

Figure 14. Subject CF, front view, aft anchor location.

Figure 15. Cinch buckle riding over body armor.

Figure 16. Cinch buckle located under edge of body armor.

Figures 9 through 14 show at least three variations on how the shoulder straps were positioned by the subjects over the survival vest. Subject MF (Figure 10) positioned the straps outboard to keep the straps from chafing his neck as seen in Figure 12. Figure 10 also shows the straps riding over the survival radio and first aid kit which could become damaged under high "G" loading because they were sandwiched between the subject's torso and the straps. A loose crotch strap may allow the subject to move placing increased pressure on the gear.

Figure 14 shows the straps inboard of the survival vest gear with the straps bearing on the subject's neck.

Figures 15 and 16 show two positions of the lap belt take-up buckle. Figure 15 shows how pressure is exerted by the edge of the buckle, and Figure 16 shows belt pressure distributed across the webbing. The position of the lap belt take-up buckle will depend on how the subject is strapped into the seat.

Several subjects had difficulty inserting the attaching spades while wearing the body armor and survival vest because they could not see the release mechanism (see Figure 17).

Tables 5 and 6 list the data obtained with respect to the lumbar support and the subject's eye position. The erect eye position corresponds to MIL-STD-1333 at the 14 degree back tangent angle, but is approximately 1 inch less in eye height.

CONCLUSIONS

1. The current lap belt anchor position should be retained for the following reasons:

a. Comments by the subjects did not reveal a positive effect from moving the attaching point rearward as was indicated to be a solution prior to the initiation of this investigation.

b. The measured SRP is forward and above the design position which moves the anchor position aft and downward with respect to the new SRP. Hence, the recommended relocation has been compensated for to some degree.

2. The crotch strap does not maintain tension across all subjects.

3. Normal wear of the retraint harness was adversely affected when the subjects wore the sur ival vest.

Figure 17. Vision restriction.

TABLE 5

Data Table

Subject	Protective Gear	Lumbar Support Height Referenced to SRP Parallel to Back (Inches)	Eye Position (Inches)									
			Relating to Floor				Relating to SRP					
			Erect		Relaxed		Erect		Relaxed		Slump	
			Vert	For	Vert	For	Vert	For	Vert	For	Vert	For
MF	W		42.9	21.2	42.6	22.7	29.4	6.0	29.1	7.5	0.3	1.5
	WO	9.9	42.7	19.0	42.0	21.2	29.2	3.8	2[illegible].5	6.0	0.7	2.2
	Δ		-		-		-		-		0.4	0.7
DY	W		44.2	22.0	42.2	25.0	28.9	7.1	27.0	10.1	1.9	3.0
	WO	11.4	42.9	21.6	42.4	22.7	27.6	6.7	27.1	7.8	0.5	1.1
	Δ		-		-		-		-		-1.4	-1.9
HB	W		42.3	20.2	41.9	20.4	27.5	4.7	27.1	4.7	0.4	0.0
	WO	9.6	42.6	21.0	41.5	21.7	27.8	5.5	26.7	6.2	1.1	0.7
	Δ		-		-		-		-		0.7	0.7
TF	W		43.5	21.5	42.2	24.3	29.3	6.1	28.0	8.9	1.3	2.8
	WO	9.8	44.2	20.1	42.4	24.0	30.0	4.6	28.2	8.6	1.8	4.0
	Δ		-		-		-		-		0.5	1.2
JW	W		43.3	19.8	42.1	21.8	31.0	4.9	28.8	6.9	2.2	2.0
	WO	9.5	-		-		-		-		-	
	Δ		-		-		-		-		-	
DH	W		43.2	19.8	42.7	21.2	31.5	5.0	31.0	7.0	0.5	2.0
	WO	9.7	43.0	20.6	42.2	21.6	31.3	5.8	30.5	6.8	1.8	3.0
	Δ		-		-		-		-		1.3	1.0
PG	W		43.4	18.9	42.4	20.1	31.7	4.1	30.7	5.3	1.0	1.2
	WO	9.8	43.5	20.0	42.5	20.6	31.8	5.2	30.8	5.8	1.0	0.6
	Δ		-		-		-		-		0.0	-0.6
CF	W		43.4	21.5	41.9	22.3	30.5	[illegible].4	29.0	7.2	1.5	0.8
	WO	11.4	43.0	21.4	41.7	22.7	30.1	6.3	28.8	7.6	1.3	1.3
	Δ		-		-		-		-		-0.2	0.5

TABLE 6

Seat Reference Point Summary Data
(Inches)

	Lumbar Support Height	Erect Eye Position				Slump			
		Without[a]		With[a]		Without		With	
		Vert	Hor	Vert	Hor	Down	Forward	Down	Forward
$\bar{X}$	0.1	29.7	5.4	30.0	5.5	1.2	1.8	1.1	1.7
S	0.8	1.6	1.0	1.5	1.0	0.5	1.3	0.7	1.0

[a]With = With body armor; Without = Without body armor.

APPENDIX

PROBLEMS IN LOCATING THE SEAT REFERENCE POINT

With reference to MIL-STD-1333, "Aircrew Station Geometry for Military Aircraft," the seat reference point (SRP) is the singular point which relates the dimensions of a person to that of the airframe. The design eye position, while fixed within the crew station, tends to be of secondary importance when motion envelopes and seat design are being inscribed within the crew station. Unfortunately, the SRP is not a specific point on the human torso, but instead, is located in space behind the seated pilot. It is defined by the intersection of two planes, the back tangent plane and the horizontal buttock reference plane, which is formed when a subject is seated.

The specific problem involved in this investigation was to insure that the relationship between the lap belt anchor point and the SRP was correct and according to specifications so that a valid judgment could be made whether to move the existing seat belt location. It was also suspected that the SRP would move from the design point when the subject was outfitted with body armor and survival vest. If this were to occur, then the relationship between the SRP and the anchor point would change and perhaps introduce unknown variables when the anchor point was moved.

Classical anthropometric measurements are made using unclothed individuals seated on a hard flat horizontal surface. The SRP is obtained by constructing a second hard flat seat back surface at the desired angle (normally 13 degrees) and having the subjects sit in the seat. The subjects are asked to square their shoulders and sit erect against the back surface. Both surfaces define the reference planes by contacting the most aft and down protuberances of the subject's back and buttocks. Of primary concern was to transpose this definition to subjects wearing clothing and seated on molded cushions. This was done by inserting probes through the cushions and seat structure, which could be measured and related to the two reference planes. The desired location for the buttock probes was below the tuberosity protubances on the subject's pelvic bones, and there was no guarantee that these would be the lowest parts because of the interaction of the buttock muscles, cushions, body armor, and survival vest.

A reference point for a back protubance is not defined in either MIL-STD-1333, MIL-S-58095, or USARTL-TR-79-22D.[1] It was initially thought that portions of the upper pelvic bone and scapula bones could be used as the aft protuberances. But when the individuals were seated in the AAH seat, portions of the major trapezius muscle on either side of the backbone proruded farther aft than the scapula bones. The back cushion molded the

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[1]Aircraft crash survival guide. Vol IV, Aircraft seat restraints, litters, and padding. June 1980.

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subject's shoulders to a more rounded shape when seated erect in the design eye position. When the subjects had their right arm in a position to handle the cyclic control, their backs were further rounded. The torso was held in a more rigid shape when the subjects wore body armor and survival vest. The lumbar support then became a fulcrum which prevented the upper torso from resting in the back cushion unless the subjects forced themselves into the cushion. These factors resulted in back tangent angles of 11.2 to 14.3 degrees.